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A FORTRAN SUBROUTINE TO PRODUCE PLOTS OF TWO DI MENSIONAL SURFACES USING A LINE PRINTER

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

A FORTRAN subroutine has been written to produce line printer plots of a function of two variables, f(x, y), using the CDC-3800. Line printer plots are valuable for users who want a fast and economical method of producing plots but do not require a high resolution capability.

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1.0 IDENTIFICATION

1.1 Title

Line Printer Plots of Two-Dimensional Surfaces

1.2 Identification Name

J5-NRL-SURFPLØT

1.3 Classification Code

J5-Output, Plotting

1.4 RCC Identification Number

J5008Ø00

1.5 Entry Points

SURFPLØT

1.6 Programming Language

Language: 3600/3800 FØRTRAN

Routine Type: Subroutine

Operating System: DRUM SCØPE 2.1

1.7 Computer and Configuration

CDC-3800

1.8 Contributor or Programmer

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Radar Division

1.9 Contributing Organization

NRL - Naval Research Laboratory,
Washington, D.C. 20375

Manuscript submitted February 15, 1974.

1.10 Program Availability

1.10.1 Submittal:

Program write-up, Fortran source deck with comments, source listing.

1.10.2 On File:

RCC Program Library

1.11 Verification

A sequence of Cassini Ovals, defined by the equation $[(x + a)^2 + y^2][(x - a)^2 + y^2] = k^4$, where k equals the amplitude and a equals the constant 3.0, was used to test SURFPLØT. Several different subroutine parameter values were used. The resultant plots compared favorably with those produced by the contour plotting program J5-ØRNL-CØNTØUR on the CalComp plotter.

1.12 Date

November 1973

2.0 PURPOSE

2.1 Description of the Routine

The routine SURFPLØT generates a plot of two-dimensional surfaces using the line printer. The plot is a plan view of the surface; the amplitude at each (x, y) point is represented by a shade of gray. The gray shading is created by overprinting with the line printer using three line printer strikes for each finished line in the plot. The cost in turn-around time using this routine is modest as it can use either of the NRL CDC-3800 systems and it avoids the queue at the CalComp plotter. There is logic to handle arrays that are too large to or do not reside in memory at one time by doing the plotting piecemeal. The plotting is ordinarily accomplished with minimal user involvement, however the user can control the nature of the plot. The array of f(x,y) values plotted is left undisturbed by SURFPLØT.

The plot returned by SURFPLØT is the same in principle as shading each bounded region in a contour plot with a distinct shade of gray that corresponds to the levels that have defined the region. There are normally ten distinguishable shades of gray (including unmarked paper) that have been created with the line printer character sets. This number is not ironclad and is subject to vagaries of paper and ribbon. However, the gray shades generally are satisfactory using the full ten shades of gray during daytime runs at NRL with either system.

The operation of SURFPLØT is ordinarily as follows:

(1) The array of f(x,y) values is searched for the maximum and minimum values.

(2) The range from maximum to minimum is divided by ten partitioning values using a linear scale (see Figure 1).

(3) The array of f(x,y) values is then searched point-by-point generating a quantized representation of each row, a row at a time, using the partitioning from step (2).

(4) The points are printed, a row at a time, using the shade of gray unique to the quantization at each (x,y) point.

The physical plot of the array of f(x,y) values is printed so that the columns of the array are parallel to the sprocket holes in the line printer paper. The rows are printed across the page. The line printer has a resolution of ten characters per inch across the page and six lines per inch along the sprocket holes. Hence, the aspect ratio is not one. There is no limitation in the number of rows (equivalent to printer lines) other than the one provided by the line count on the RUN card. However, no more than 128 columns can be printed on any one printer page. For arrays that have more than 128 columns, the plot is printed out in blocks of 100

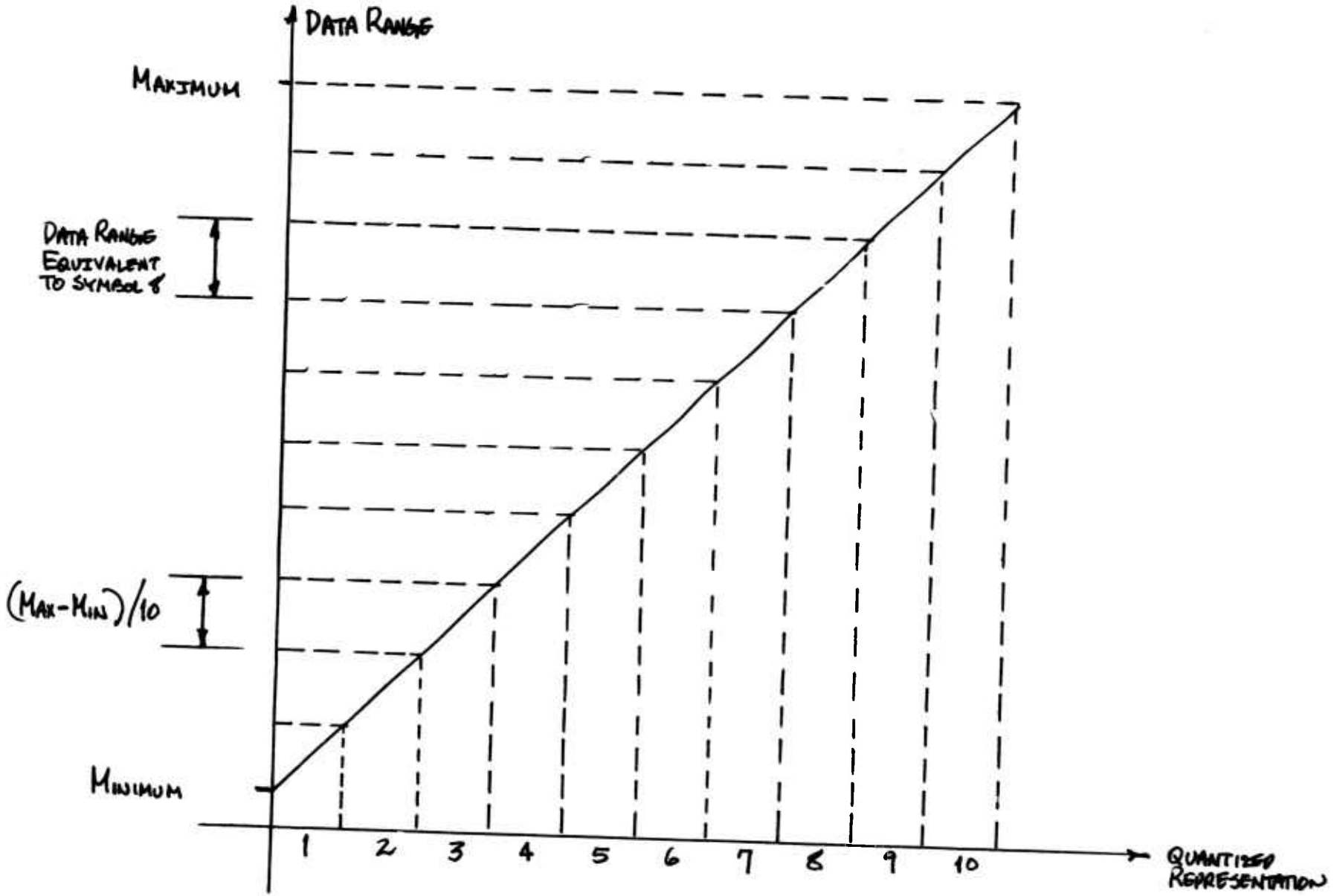


Fig. 1 - Partitioning of Data Range with a Linear Scale

columns per page (the routine automatically accomplishes this step) with each page annotated (see Section 3.8).

There are three functional pieces to SURFPLØT:

(1) generation of the quantization levels used to represent f(x,y) and the equivalent shade of gray,

(2) generation of the annotation, and

(3) generation of the line printer image of the array of f(x,y) values with the notation into line printer statements and the printing.

The user can be involved heavily, partially, or not at all in the first area and thereby exercise control over the nature of the plot. The number of shades of gray and the type of scale are just two of the variables that can be controlled, if desired. Only when the plot is done piecemeal is the user involved in (3) and then only in the most minimal fashion.

2.2 Problem Background

Most of the available routines for plotting in the RCC library are for functions of one variable. Representative routines that can plot an array of f(x,y) values include the CalComp THREE-D Plotting Routine, J5-NRL-PLØTISØM, J5-NRL-SURFACE, and J5-ØRNL-CØNTØUR. These four routines can give an excellent representation of the function surface, however they require the use of a CalComp plotter. SURFPLØT is a simple plotting routine that returns a usable image of the function surface with minimum cost in turn-around time and minimal user involvement. For situations where the point by point generation of an image of f(x,y) is useful, more flexible control of the image generation is available.

3.0 USAGE

3.1 Calling Sequence or Operational Procedure

```
CALL SURFPLØT (ZDATA, IXLENGTH, JYLENGTH,
ITITLE, ISCALE, ZSCALE, ZLEVEL, ZPARAMTR,
IEXTEND, ISEARCH)
```

The calling sequence used is the same form whatever the level of control being exercised by the user. The number of parameters that need be specified, however, vary depending on (1) a single or multiple call to SURFPLØT and (2) the degree of control exercised by the user over the nature of the plot. The user always names the array of f(x,y) values, its dimensions and sets up a title. All that need be done thereafter is to dimension properly the remaining arrays and a linearly scaled plot will result. To exercise control over the plot, the parameters used are ISCALE, ZSCALE, and occasionally ZLEVEL and ZPARAMTR. To plot piecemeal or with several calls one appropriately sets ZPARAMTR, IEXTEND, AND ISEARCH.

3.2 Arguments, Parameters, and/or Initial Conditions

The user must dimension all arrays in the calling program.

ZDATA - the name of the array containing the f(x,y) values, which can be either fixed or floating point. The array is left undisturbed by SURFPLØT.
DIMENSION ZDATA (IXLENGTH, JYLENGTH)

IXLENGTH - the number of rows in ZDATA

JYLENGTH - the number of columns in ZDATA

ITITLE - the name of the array containing the plot title, one card of BCD characters.
DIMENSION ITITLE (10). See Section 7.0.

While the above four parameters must be specified in each call, the remaining parameters are optional. The next group: ISCALE, ZSCALE, and occasionally ZLEVEL and/or ZPARAMTR, are used to control the plotting.

ISCALE - the name of an array of four numbers that selects the number of shades of gray, the type of scale, a "positive" or "negative", and indicates whether the elements of ZDATA are fixed or floating point numbers. DIMENSION ISCALE(4).

ISCALE(1) =
- 0 - ten shades of gray (as shown in the sample plot in Section 7.0.)
- 1-25 ISCALE(1) shades of gray - if more than ten, the user must supply the symbol set using three data cards. These cards are read in under a 25(R1) format. There is an interaction with ISCALE(3); when zero the first symbol on the card will represent the smallest amplitude and when non-zero the largest. See Section 3.7.

ISCALE(2) =
- 0 - Linear Scale
- 1 - Logarithmic Scale
- 2 - Logarithm of sine to the pth* power
- 3 - sine to the pth* power
- 4 - user supplied; the quantizing levels must be in ZLEVEL

ISCALE(3) =
- 0 - increasing amplitude printed as increasing darkness - a "negative". Probably the most useable form.
- 1 - decreasing amplitude printed as increasing darkness - a "positive".

*If ISCALE(2) = 2, p = 2.5
*If ISCALE(2) = 3, p = 0.25

ISCALE(4) =
- 0 - the elements of the array ZDATA are floating point numbers.
- 1 - the elements of the array ZDATA are fixed point numbers.

ZSCALE - the name of an array of three numbers used to generate the quantizing levels in ZLEVEL. A full explanation of the meanings of ZSCALE is deferred to Section 4.0 where the algorithms for generating ZLEVEL are explained. Along with ISCALE, ZSCALE can be used to exercise complete control over the plotting. By leaving ZSCALE(·) = 0.00, the present parameters will be selected. To use ZSCALE(·) with other than nominal values, see Tables 1 & 2, Section 4. DIMENSION ZSCALE(3).

ZLEVEL - the name of an array of quantizing values generated by SURFPLØT. If ISCALE(2) ≠4, the user need only dimension ZLEVEL. If ISCALE(2) = 4, the user supplies the quantizing levels in ZLEVEL (see Section 4.) DIMENSION ZLEVEL(10) or ZLEVEL(ISCALE(1)) if more than ten shades of gray are used.

The last group of parameters is used when the plot is made with several successive calls to SURFPLØT.

ZPARAMTR - the name of an array containing:

ZPARAMTR(1) = maximum value of f(x,y)
ZPARAMTR(2) = value of x for $f_{max}(x,y)$
ZPARAMTR(3) = value of y for $f_{max}(x,y)$
ZPARAMTR(4) = minimum value of f(x,y)
ZPARAMTR(5) = value of x for $f_{min}(x,y)$
ZPARAMTR(6) = value of y for $f_{min}(x,y)$

In the multiple call situation, to have the same scale for all portions of the plot, the scale routines must be given the maximum and minimum values of f(x,y) at the start. This is accomplished by filling ZPARAMTR(·) with the appropriate values. If left zero, the first portion of the array that is plotted will be searched and the scales from this first portion

will be used for the remaining portions. In the single call case, ZPARAMTR returns the maximum and minimum parameters of the plotted array. DIMENSION ZPARAMTR(6).

IEXTEND - the name of an array containing multiple call indicators; IEXTEND(1) denotes that the extensions will be in the x-direction (parallel to the sprocket holes), IEXTEND(2) for y-direction extensions. Either one or both extensions can be called. DIMENSION IEXTEND(2). The following code is used.

IEXTEND =
- 0 - only one call in this direction
- 1 - first of successive calls in this direction
- 2 - neither first nor last call
- 3 - last of successive calls

ISEARCH - a variable used in multiple call situations to force the scales to be recomputed for each separate call in the sequence. This means that the scales change (presumably) for each call. The only reason for including this option is that the maximum and minimum values of f(x,y) can be found for the extended array from the maximum and minimum values returned in ZPARAMTR(·) for each section of f(x,y). A plot of each section also is printed.

ISEARCH =
- 0 - scales are not recomputed
- 1 - scales are recomputed

3.3 Space Required (Decimal and Octal)

3.3.1 Unique Storage

6100 octal (3136 decimal) locations

3.3.2 Common Blocks

None

3.3.3 Temporary Storage

None

3.4 Messages and Instructions to the Operator

None

3.5 Error Returns, Messages, and Codes

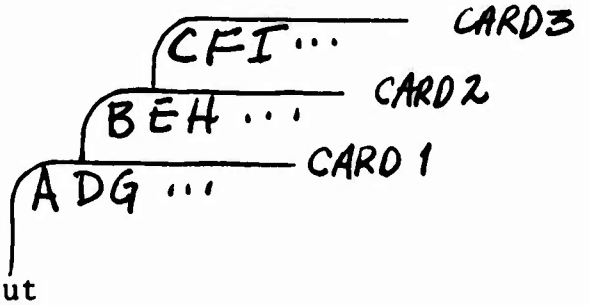
None

3.6 Informative Messages to the User

None

3.7 Input

In addition to a card containing the title, input is required when the user supplies the symbol set to define the shades of gray. Up to 25 shades can be defined. Each shade is made up of three characters from the line printer set as read in from three data cards punched in a 25(R1) format. In the example below the first gray level is the character A overprinted with a B and C.



3.8 Output

A typical output is shown in Section 7. In addition to the line printer plot, the following information is printed:

(N,M) SURFACE PLOT.....Page N1 of N2
The (N,M) refers to multiple call situations and is used to annotate each portion of the overall plot as an element in a matrix. N is the row index and M is the column index. For the single call case, N = M = 1.

The page numbering accounts for arrays with more than 128 columns; then the plot will be made 100 columns per page with the N1 and N2 annotating this string.

ITITLE - the user supplied title.

DATA MAXIMUM.....the maximum value of f(x,y) and its (x,y) location in the array (the first occurrence of $f_{max}(x,y)$)

DATA MINIMUM.....the minimum value of f(x,y) and its (x,y) location in the array (the first occurrence of $f_{min}(x,y)$)

DATA RANGE.....if linear plot, $(f_{max}-f_{min})$; if logarithmic, $C \cdot \log_{10}(f_{max}/f_{min})$ where C is equal to 10.00 unless otherwise specified by the user. See Tables 1 & 2, Section 4.

SCALE MAXIMUM.....maximum value of the quantizing levels

SCALE MINIMUM.....minimum value of the quantizing levels

SCALE RANGE.....if linear, $(Scale_{max} - Scale_{min})$ quantizing levels; if log, $C \cdot \log_{10}(Scale_{max}/Scale_{min})$, C defined as above.

PLOT REFERENCE.....if linear, $(f_{max}-f_{min})$ unless specified by the user; if log, either f_{max}, $f_{max}/2.00$, or user supplied. See Tables 1 & 2, Section 4.0.

PLOT BIAS.....for linear scales, nominally $f_{min}(x,y)$ unless otherwise specified by the user; if log scale, it will be 0.00.

PLOT EXTENT.....the dimensions of the array of f(x,y) values (IXLENGTH, JYLENGTH)

DB REFERENCE.....the "C" used to compute decibels. If ZSCALE(2) = 0, DB REFERENCE = 10.00; if ZSCALE(2)≠0, DB REFERENCE = ZSCALE(2).

HALF TONE DENSITY WEDGE AND SCALE

The equivalence between shades of gray and numerical values and the relation to the data. If linear, percentage of the maximum; if log, decibels relative to the maximum*. Five rows of the gray scale, each gray shade repeated for ten points, are printed. If more than ten shades of gray have been specified the wedge is printed along the page rather than across the page.

The body of the plot follows. A border of ▮ is printed around the periphery. Every fifth row and column are numbered, the maximum and minimum of the array of f(x,y) values are labeled (only the first occurrence of each). The program will keep track of multiple call plots so that the numbering is consistent and the borders removed appropriately to ease the cutting and pasting.

After completion of the call, the array ZPARAMTR contains the maximum and minimum parameters of the array (see Section 3.2) and the array ZLEVEL contains the quantizing level values.

3.9 Formats

See Section 3.7.

3.10 External Routines and Symbols

None

3.11 Timing

The routine takes roughly 0.07 seconds per row of the array of f(x,y) values.

---

*decibels are conventionally defined as 10 log(·) = dB

3.12 Accuracy

Not applicable

3.13 Cautions to Users

The aspect ratio of the plot is not one so a distortion exists due to the stretching of the x-axis relative to the y-axis.

This imaging does not work well with small or thin arrays, for the technique depends on the eye perceiving structures in the data. If the gray shade does not have enough spatial extent, the eye does not perceive a pattern.

3.14 Program Deck Structure

```
7
9JØB
7
9FTN
  user program (contains call to SURFPLØT)
  SUBROUTINE SURFPLØT
             SCØPE
7
9LØAD
7
9RUN
  data card 1 - title card
  data card 2)  plotting symbols if more than
  data card 3}- ten shades of gray are
  data card 4)  requested.
  end-of-file card
```

3.15 References - Literature - Appendices

[1] D. E. Knuth, The Art of Computer Programming, Volume 2 - Seminumerical Algorithms, Addison - Wesley, 1969.

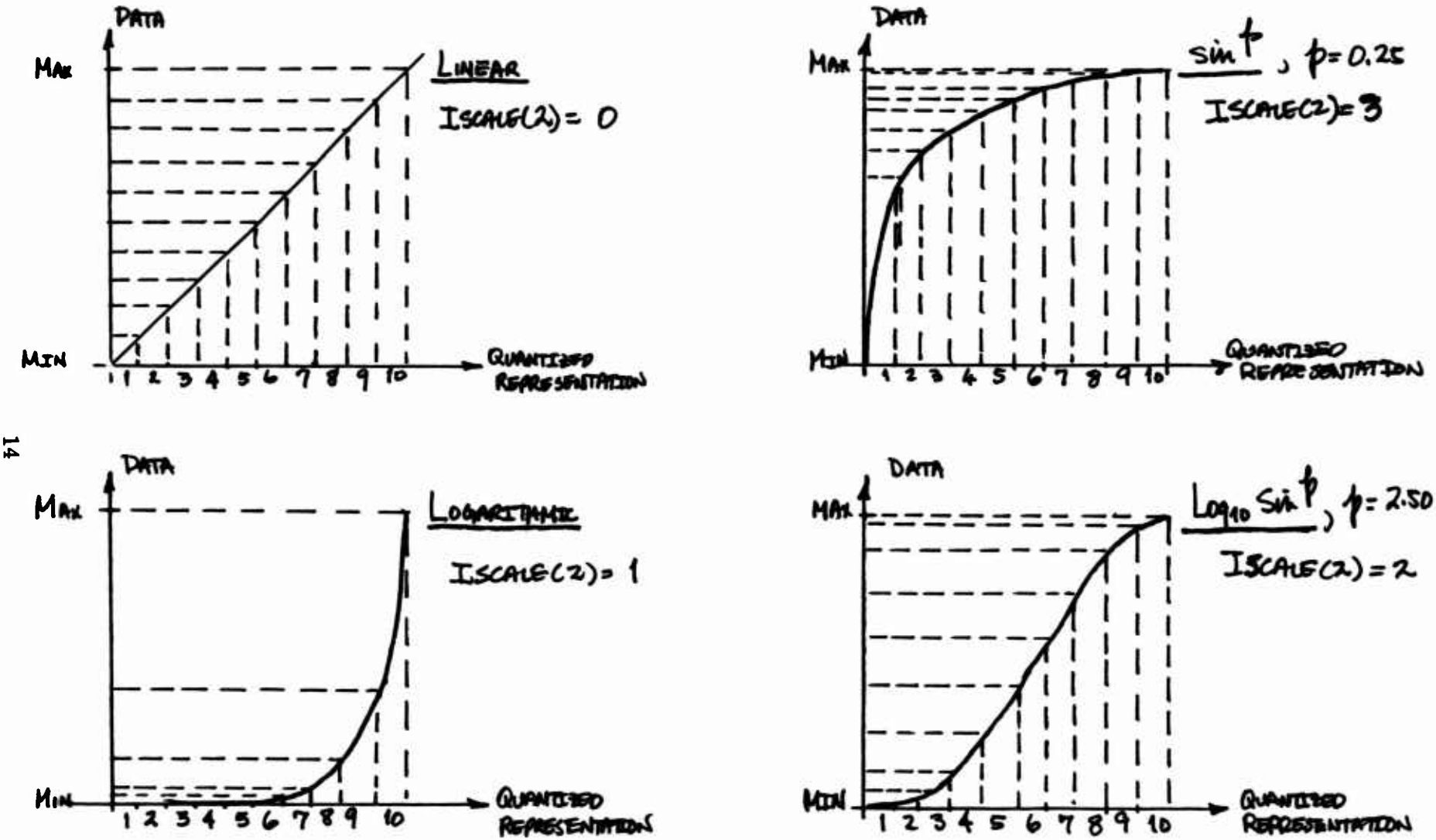


Fig. 2 - Rough Transfer Characteristics for Data Scales 0 through 3

4.0 METHOD OR ALGORITHM

Representing a function of two variables on a flat piece of paper so that its structure is obvious to the eye requires some trickery. The surface can be suggested by encoding the amplitude of each (x,y) point into a pseudo-height interpretable by the eye. Some standard methods are:

(a) mapping amplitude into brightness as in a photograph,
(b) mapping constant amplitude contours as in the topographic map,
(c) using isometric distortions (or projections) by mapping amplitude for each row (or column) into y-axis deflection then offsetting each succeeding row a fixed amount in the x-and y-directions, and
(d) mapping regions of constant amplitude or amplitude bands into colors or shades of gray as in a color relief map.

SURFPLØT follows method (d). The data f(x,y) is partitioned into bands, each band is assigned a unique shade of gray, and the array of f(x,y) values is printed point by point following this code.

The technique of selecting the amplitude bands is not straightforward. In Figure 2 four different partitionings of the data range are displayed. The attraction of non-linear scales is simply that it allows the resolution of the eye, represented by the ten levels along the abscissa, to be placed over the significant detail of the data. A classical example is a monochromatic image; the array of f(x,y) values representing the image often has considerable dynamic range. However, on closer examination, the distribution of amplitudes often turns out to be confined to a small portion of the dynamic range not far from the minimum value with a few very large specular returns. The information content is in this small portion of the dynamic range near the minimum; hence a logarithmic scale would be an appropriate technique to use for partitioning the dynamic range, (see Figure 2).

In constructing a partition of the data there are three features available to the user for control:

(1) the number of bands,
(2) the shape of the partitioning curve, and
(3) the location of the partitioning curve.

Examples of (2) are shown in Figure 2. An example of (3) for linear scales is shown in Figure 3. In SURFPLØT, the first two features are specified by ISCALE (1) and ISCALE (2) respectively. To specify the third feature, the program uses ISCALE(1), ZSCALE(1), ZSCALE(2) and ZSCALE(3). The partitioning values are located in array ZLEVEL. Table 1 shows how each scale is computed; Table 2 shows the specification of the third feature. The following pattern is used; if ZSCALE(·) is left zero, a preset value is used. If non-zero, that value of ZSCALE(·) is used. In the case of ZSCALE(1), a third option is provided. If ZSCALE(1) = -1.00, then half the preset value is used. This is most useful in logarithmic plots as it slides the scale down 3dB below the maximum.

The plotting consists of printing one of a series of half-tone-like shades of gray at each point corresponding to the f(x,y) value at that point. The shade of gray is determined by finding the partitioning level that just equals or exceeds the f(x,y) value. Assigned to each partitioning level is a unique shade of gray created by overprinting with three line printer characters. The array is examined row by row; printing is also accomplished row by row. The data array is unaltered.

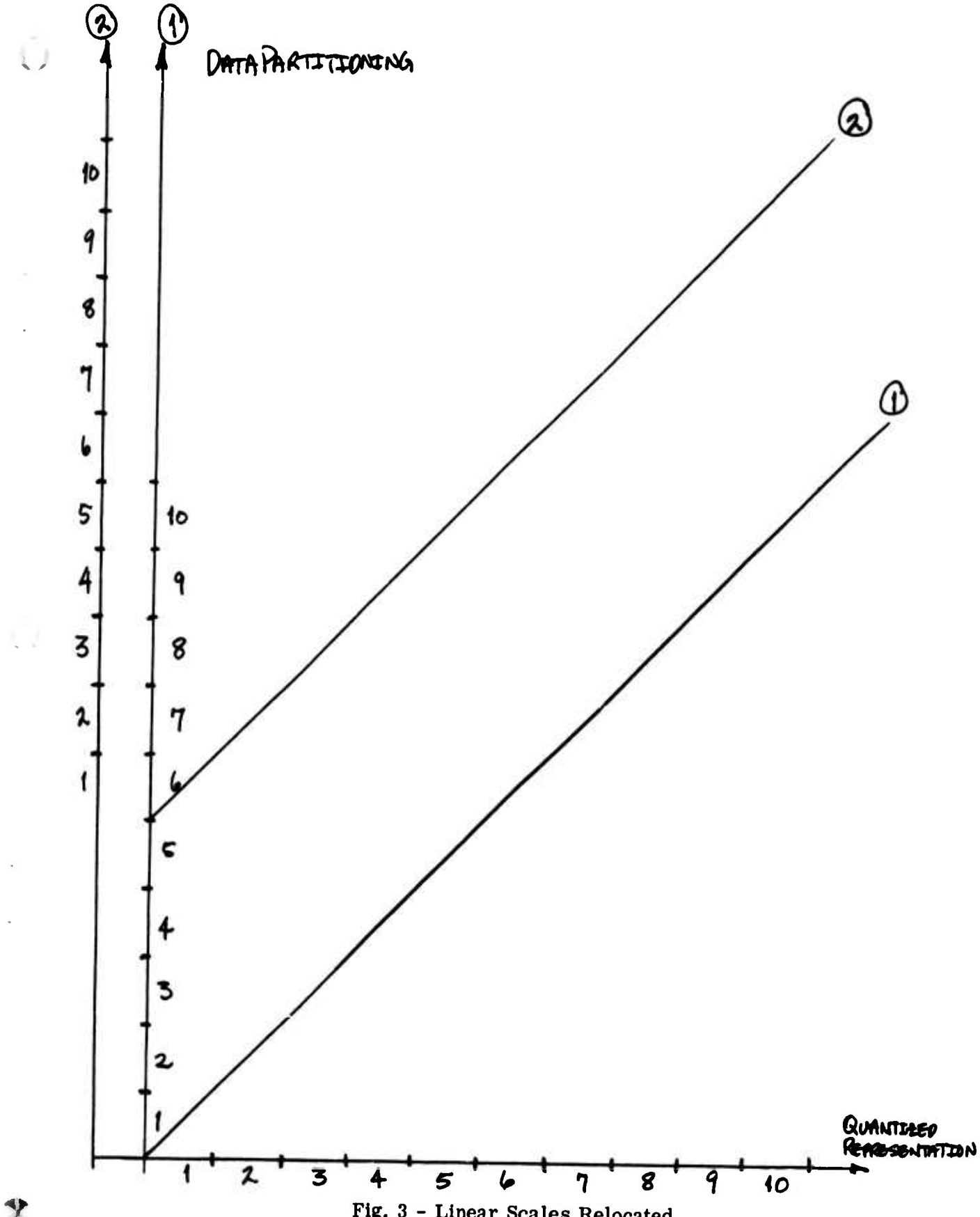


Fig. 3 - Linear Scales Relocated

TABLE 1 - SCALE ALGORITHMS

SCALE TYPE	ZLEVEL(L) =	ZLEVEL(L)/ZMAX OR DBSCALE * LOG_{10}(ZLEVEL(L)/ZMAX)	SCALE RANGE
LINEAR ISCALE(2)=0	$ZBIAS + \frac{ZREF}{LLEVELS} * L$	$\frac{ZBIAS}{ZMAX} + \frac{ZREF}{ZMAX} * \frac{L}{LLEVELS}$	$ZREF * \frac{LLEVELS-1}{LLEVELS}$
LOGARITHMIC ISCALE(2)=1	$ZREF * 10.00 ** \{-SLOPE * (1 - \frac{L}{LLEVELS})\}$	$DBSCALE * LOG_{10} \frac{ZREF}{ZMAX} - DBSCALE * SLOPE * (1 - \frac{L}{LLEVELS})$ (IN dB)	$DBSCALE * SLOPE * \frac{LLEVELS-1}{LLEVELS}$ (IN dB)
LOG-SINP ISCALE(2)=2	$ZREF * \{SINF(\frac{\pi}{2} \frac{L}{LLEVELS})\} ** POWER$	$DBSCALE * LOG_{10} \frac{ZREF}{ZMAX} - DBSCALE * POWER * LOG_{10}(SINF \frac{\pi}{2} \frac{L}{LLEVELS})$	$-DBSCALE * POWER * LOG_{10}(SINF \frac{\pi}{2} \frac{1}{LLEVELS})$
SINP ISCALE(2)=3	$ZBIAS + ZREF * \{SINF \frac{\pi}{2} \frac{L}{LLEVELS}\} ** POWER$	$\frac{ZBIAS}{ZMAX} + \frac{ZREF}{ZMAX} * \{SINF(\frac{\pi}{2} \frac{L}{LLEVELS})\} ** POWER$	$ZREF * \{1 - [SINF \frac{\pi}{2} \frac{1}{LLEVELS}] ** POWER\}$
USER DEFINED ISCALE(2)=4	ZLEVEL(L) defined in calling program	$\frac{ZLEVEL(L)}{ZMAX}$	ZLEVEL(LLEVELS) - ZLEVEL(1)

TABLE 2 - DEFINITION OF TERMS

SCALE TYPE	REFERENCE VALUE (ZREF) ZSCALE(1) =	ZREF =	BIAS OR dB CONSTANT ZSCALE(2) =		POWER OR SLOPE ZSCALE(3) =	
LINEAR ISCALE(2)=0	0.00	ZMAX-ZMIN	0.00	ZBIAS = ZMIN	0.00	NOT USED
	-1.00	(ZMAX-ZMIN)/2	≠0.00	= ZSCALE(2)	≠0.00	NOT USED
	NEITHER OF ABOVE	ZSCALE(1)				
LOGARITHMIC ISCALE(2)=1	0.00	ZMAX	0.00	DBSCALE = 10.00	0.00	SLOPE = 40/DBSCALE
	-1.00	ZMAX/2.00	≠0.00	= ZSCALE(2)	≠0.00	= ZSCALE(3)
	NEITHER	ZSCALE(1)				
LOG-SIN^P ISCALE(2)=2	0.00	ZMAX	0.00	DBSCALE = 10.00	0.00	POWER = 2.5 − (LEVELS−10)/40
	-1.00	ZMAX/2.00	≠0.00	= ZSCALE(2)	≠0.00	= ZSCALE(3)
	NEITHER	ZSCALE(1)				
SIN^P ISCALE(2)=3	0.00	ZMAX-ZMIN	=0.00	ZBIAS = ZMIN	0.00	POWER = 2.5 − (LEVELS−10)/40
	-1.00	(ZMAX-ZMIN)/2.00	≠0.00	= ZSCALE(2)	≠0.00	= ZSCALE(3)
	NEITHER	ZSCALE(1)				
USER DEFINED ISCALE(2)=4	ZREF = ZSCALE(1)		NOT USED		NOT USED	

5.0 SOURCE LANGUAGE LISTING

```
J5 NRL SURFPLOT  LINE PRINTER PLOTS OF TWO-DIMENSIONAL SURFACES
      SUBROUTINE SURFPLOT(ZDATA,IXLENGTH,JYLENGTH,ITITLE,ISCALE,ZSCALE, 00000100
     1                    ZLEVEL,ZPARAMTR,IEXTEND,ISEARCH)              00000200
                                                                       00000300
C     IDENT NUMBER - J5008000                                          00000400
C     TITLE - LINE PRINTER PLOTS OF TWO DIMENSIONAL SURFACES           00000500
C     IDENT NAME - J5-NRL-SURFPLOT                                     00000600
C     LANGUAGE - FORTRAN                                               00000700
C     COMPUTER - CDC-3800                                              00000800
C     CONTRIBUTOR - MICHAEL A. TAMNY, CODE 5365T, AIRBORNE RADAR BRANCH,00000900
C                                 RADAR DIVISION                       00001000
C     ORGANIZATION - NRL - NAVAL RESEARCH LABORATORY - WASHINGTON, D.C. 00001100
C                                                     20375            00001200
C     DATE - 31 OCTOBER 1973                                           00001300
C     PURPOSE - TO PLOT AN ARRAY OF F(X,Y) VALUES USING THE LINE PRINTER00001400
C     BY REPRESENTING AMPLITUDE WITH A SHADE OF GRAY                   00001500
                                                                       00001600
                                                                       00001700
                                                                       00001800
      DIMENSION ZDATA(1)                                               00001900
      DIMENSION ZPARAMTR(1)                                            00002000
      DIMENSION IEXTEND(1)                                             00002100
      DIMENSION ISCALE(1)                                              00002200
      DIMENSION ZSCALE(1)                                              00002300
      DIMENSION ZLEVEL(1)                                              00002400
      DIMENSION ITITLE(1)                                              00002500
      DIMENSION LINEPLOT(135,3)                                        00002600
      DIMENSION LINE1(135), LINE2(135), LINE3(135)                     00002700
      DIMENSION JLINE(17,3)                                            00002800
      DIMENSION LINESYM(25,3)                                          00002900
                                                                       00003000
      EQUIVALENCE ( LINEPLOT(  1),LINE1(1) )                           00003100
      EQUIVALENCE ( LINEPLOT(136),LINE2(1) )                           00003200
      EQUIVALENCE ( LINEPLOT(271),LINE3(1) )                           00003300
      EQUIVALENCE ( LINEPLOT(  1),JLINE(1) )                           00003400
      EQUIVALENCE ( ZTEST,ITEST )                                      00003500
                                                                       00003600
      TYPE INTEGER BLNKFILL, DBFILL                                    00003700
      TYPE INTEGER BLANK, DOT, PLUS                                    00003800
      TYPE INTEGER AFILL, IFILL, MFILL, NFILL, OFILL, WFILL, XFILL     00003900
                                                                       00004000
      DATA (BLNKFILL = 2R  ), (DBFILL = 2RDB)                          00004100
      DATA (BLANK = 1R ), (DOT = 1R.), (PLUS = 1R+)                    00004200
      DATA (AFILL = 1RA), (IFILL = 1RI), (MFILL = 1RM), (NFILL = 1RN)  00004300
      DATA (WFILL = 1RW), (XFILL = 1RX)                                00004400
      DATA (NX = 1), (NY = 1)                                          00004500
      DATA((LINESYM(L,1),L=1,10)=1R ,1R-,1R+,1R*,1RX,2(1RO),1RU,1RO,1RD)00004600
      DATA((LINESYM(L,2),L=1,10)=6(1R ),1RX,1RA,1R+,1RB)               00004700
      DATA((LINESYM(L,3),L=1,10)=8(1R ),1RU,1RX)                       00004800
      DATA (ISHIFT1 = 1000000000000000B)                               00004900
```

```
      DATA (ISHIFT2 = 10000000000008)                                    00005000
      DATA (ISHIFT3 = 1000000000B)                                       00005100
      DATA (ISHIFT4 = 100000008)                                         00005200
      DATA (ISHIFT5 = 10000B)                                            00005300
      DATA (ISHIFT6 = 1000B)                                             00005400
      DATA (ISHIFT7 = 100B)                                              00005500
                                                                         00005600
                                                                         00005700
                                                                         00005800
      GO TO ( 1005,1008 ) NX + NY                                        00005900
                                                                         00006000
                                                                         00006100
C     THIS TRAP IS USED TO RECOGNIZE THE TYPE OF CYCLE IN EXTENDED       00006110
C     CALLS IN BOTH DIMENSIONS. THE FIRST CALL OF THIS TYPE CAUSES       00006120
C     NX = NY = 0. OTHERWISE THEY ARE INDICIES USED TO KEEP TRACK OF     00006130
C     THE ARRAY BLOCKS SENT TO SURFPLOT FOR PRINTING AND AS SUCH ARE     00006140
C     GREATER THAN OR EQUAL TO 1.                                        00006150
                                                                         00006200
                                                                         00006300
 1005 IF( IEXTEND(1)-IEXTEND(2) .EQ. 1 ) GO TO 1006                      00006400
      NX = 1                                                             00006500
      NY = 2                                                             00006600
      ILAST = 0                                                          00006700
      IDXY = 2                                                           00006800
      GO TO 1008                                                         00006900
 1006 NY = 1                                                             00007000
      NX = 2                                                             00007100
      JLAST = 0                                                          00007200
      IDXY = 1                                                           00007300
                                                                         00007400
C     THE ARRAY IS SEARCHED FOR THE MAXIMUM AND MINIMUM VALUES AND       00007410
C     THE SCALES COMPUTED IN THE FOLLOWING MANNER..(1) IN SINGLE CALL    00007420
C     CASES..(2) IF ISEARCH = 1..(3) IF THE FIRST CALL OF AN EXTENDED    00007430
C     CALL AND THE MAXIMUM AND MINIMUM VALUES HAVE NOT BEEN PASSED IN    00007440
C     ZPARAMTR. IN THE SEARCH, LOCATIONS ARE NUMBERED IN THE EXTENDED    00007450
C     ARRAY BY BIASING WITH ILAST AND JLAST.  IF A SEARCH IS MADE THE    00007460
C     LEVELS MUST BE COMPUTED.                                           00007470
                                                                         00007500
 1008 IF( IEXTEND(1)+IEXTEND(2) .EQ. 0 ) GO TO 1009                      00007600
      IF( ISEARCH .EQ. 1 ) GO TO 1009                                    00007700
      IF( IEXTEND(1) .GT. 1 .OR. IEXTEND(2) .GT. 1 ) GO TO 1075          00007800
      IF( ZPARAMTR(1) .EQ. 0.00 .AND. ZPARAMTR(4) .EQ. 0.00 ) GO TO 1009 00007900
      GO TO 1020                                                         00008000
                                                                         00008100
                                                                         00008200
 1009 ZTEST = ZDATA(1)                                                   00008300
      IF( ISCALE(4) .EQ. 0 ) GO TO 1010                                  00008400
      ZTEST = ITEST                                                      00008500
 1010 Z MAX = Z MIN = ZTEST                                              00008600
      MAX X = MIN X = 1 + ILAST                                          00008700
```

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      MAX Y = MIN Y = 1 + JLAST                                          00008800
      DO 1015 J = 1,JYLENGTH                                             00008900
      INDEX = ( J-1 )*IXLENGTH                                           00009000
      DO 1015 I = 1,IXLENGTH                                             00009100
      ZTEST = ZDATA(INDEX+I)                                             00009200
      IF( ISCALE(4) .EQ. 0 ) GO TO 1011                                  00009300
      ZTEST = ITEST                                                      00009400
 1011 IF( ZTEST .LE. Z MAX ) GO TO 1012                                  00009500
      Z MAX = ZTEST                                                      00009600
      MAX X = I + ILAST                                                  00009700
      MAX Y = J + JLAST                                                  00009800
      GO TO 1015                                                         00009900
 1012 IF( ZTEST .GE. Z MIN ) GO TO 1015                                  00010000
      Z MIN = ZTEST                                                      00010100
      MIN X = I + ILAST                                                  00010200
      MIN Y = J + JLAST                                                  00010300
 1015 CONTINUE                                                           00010400
      ZPARAMTR(1) = Z MAX                                                00010500
      ZPARAMTR(2) = MAX X                                                00010600
      ZPARAMTR(3) = MAX Y                                                00010700
      ZPARAMTR(4) = Z MIN                                                00010800
      ZPARAMTR(5) = MIN X                                                00010900
      ZPARAMTR(6) = MIN Y                                                00011000
      IF( IEXTEND(1) .GT. 1 .OR. IEXTEND(2) .GT. 1 ) GO TO 1050          00011100
      GO TO 1030                                                         00011200
 1020 Z MAX = ZPARAMTR(1)                                                00011300
      MAX X = ZPARAMTR(2)                                                00011400
      MAX Y = ZPARAMTR(3)                                                00011500
      Z MIN = ZPARAMTR(4)                                                00011600
      MIN X = ZPARAMTR(5)                                                00011700
      MIN Y = ZPARAMTR(6)                                                00011800
                                                                         00011900
C     THIS SECTION SETS THE NUMBER OF GRAY SHADES, AND IF LESS THAN      00011910
C     TEN, SELECTS ONES FURTHER APART USING LSTEP AND LBIAS.             00011920
                                                                         00012000
 1030 IF( ISCALE(1) .GT. 10 ) GO TO 1040                                 00012100
      IF( ISCALE(1) .EQ.  0 ) LLEVELS = 10                               00012200
      IF( ISCALE(1) .NE.  0 ) LLEVELS = ISCALE(1)                        00012300
      LSTEP = 10/LLEVELS                                                 00012400
      LBIAS = 10 - LSTEP*LLEVELS                                         00012500
      GO TO 1050                                                         00012600
 1040 LLEVELS = ISCALE(1)                                                00012700
      LSTEP = 1                                                          00012800
      LBIAS = 0                                                          00012900
      READ 91041, ( LINESYM(L,1), L = 1,LLEVELS )                        00013000
      READ 91041, ( LINESYM(L,2), L = 1,LLEVELS )                        00013100
      READ 91041, ( LINESYM(L,3), L = 1,LLEVELS )                        00013200
91041 FORMAT( 25( A1 ) )                                                 00013300
                                                                         00013400
C     THIS SECTION COMPUTES THE PARTITIONING LEVELS, ZLEVEL              00013410
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                                                                        00013500
1050 GO TO ( 1051,1055,1060,1065,1070 ) ISCALE(2) + 1                   00013600
                                                                        00013700
1051 ITYPE = BLNKFILL                                                   00013800
     IF( ZSCALE(1) .EQ. 0.00 ) Z REF = ( ZMAX-ZMIN )                    00013900
     IF( ZSCALE(1) .EQ.-1.00 ) Z REF = ( ZMAX-ZMIN )/2.00               00014000
     IF( ZSCALE(1) .NE. 0.00 .AND. ZSCALE(1) .NE.-1.00 )                00014100
    1   Z REF = ZSCALE(1)                                               00014200
     IF( ZSCALE(2) .EQ. 0.00 ) Z BIAS = Z MIN                           00014300
     IF( ZSCALE(2) .NE. 0.00 ) Z BIAS = ZSCALE(2)                       00014400
     DBSCALE = 0.00                                                     00014500
     STEP = ZREF/LLEVELS                                                00014600
     DO 1052 L = 1,LLEVELS                                              00014700
     ZLEVEL(L) = Z BIAS + STEP*L                                        00014800
1052 CONTINUE                                                           00014900
     ZRANGE = Z MAX - Z MIN                                             00015000
     SCALE = ZLEVEL(LLEVELS) - ZLEVEL(1)                                00015100
     GO TO 1075                                                         00015200
                                                                        00015300
1055 ITYPE = DBFILL                                                     00015400
     IF( ZSCALE(1) .EQ. 0.00 ) Z REF = Z MAX                            00015500
     IF( ZSCALE(1) .EQ.-1.00 ) Z REF = ZMAX/2.00                        00015600
     IF( ZSCALE(1) .NE. 0.00 .AND. ZSCALE(1) .NE.-1.00 )                00015700
    1   Z REF = ZSCALE(1)                                               00015800
     IF( ZSCALE(2) .EQ. 0.00 ) DBSCALE = 10.00                          00015900
     IF( ZSCALE(2) .NE. 0.00 ) DBSCALE = ZSCALE(2)                      00016000
     IF( ZSCALE(3) .EQ. 0.00 ) SLOPE = 40.00/DBSCALE                    00016100
     IF( ZSCALE(3) .NE. 0.00 ) SLOPE = ZSCALE(3)                        00016200
     Z BIAS = 0.00                                                      00016300
     STEP = 1.00/LLEVELS                                                00016400
     DO 1056 L = 1,LLEVELS                                              00016500
     POWER = -SLOPE*( 1.00-STEP*L )                                     00016600
     ZLEVEL(L) = ZREF*( 10.00**POWER )                                  00016700
1056 CONTINUE                                                           00016800
     ZRANGE = DBSCALE*ALOG10( ZMAX/ZMIN )                               00016900
     SCALE = DBSCALE*ALOG10( ZLEVEL(LLEVELS)/ZLEVEL(1) )                00017000
     GO TO 1075                                                         00017100
                                                                        00017200
1060 ITYPE = DBFILL                                                     00017300
     IF( ZSCALE(1) .EQ. 0.00 ) Z REF = Z MAX                            00017400
     IF( ZSCALE(1) .EQ.-1.00 ) Z REF = ZMAX/2.00                        00017500
     IF( ZSCALE(1) .NE. 0.00 .AND. ZSCALE(1) .NE.-1.00 )                00017600
    1   Z REF = ZSCALE(1)                                               00017700
     IF( ZSCALE(2) .EQ. 0.00 ) DBSCALE = 10.00                          00017800
     IF( ZSCALE(2) .NE. 0.00 ) DBSCALE = ZSCALE(2)                      00017900
     IF( ZSCALE(3) .EQ. 0.00 ) POWER = 2.50                             00018000
     IF( ZSCALE(3) .NE. 0.00 ) POWER = ZSCALE(3)                        00018100
     Z BIAS = 0.00                                                      00018200
     STEP = 1.00/LLEVELS                                                00018300
     PIOVER2 = 3.14159265/2.00                                          00018400
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      RADIAN = PIOVER2*STEP                                              00018500
      DO 1061 L = 1,LLEVELS                                              00018600
      ARGUMENT = RADIAN*L                                                00018700
      ZLEVEL(L) = ZREF*( (SINF(ARGUMENT))**POWER )                       00018800
 1061 CONTINUE                                                           00018900
      SCALE = DBSCALE*ALOG10( ZLEVEL(LLEVELS)/ZLEVEL(1) )                00019000
      ZRANGE = DBSCALE*ALOG10( ZMAX/ZMIN )                               00019100
      GO TO 1075                                                         00019200
                                                                         00019300
 1065 ITYPE = BLNKFILL                                                   00019400
      IF( ZSCALE(1) .EQ. 0.00 ) Z REF = ( ZMAX-ZMIN )                    00019500
      IF( ZSCALE(1) .EQ.-1.00 ) Z REF = ( ZMAX-ZMIN )/2.00               00019600
      IF( ZSCALE(1) .NE. 0.00 .AND. ZSCALE(1) .NE.-1.00 )                00019700
     1   Z REF = ZSCALE(1)                                               00019800
      IF( ZSCALE(2) .EQ. 0.00 ) Z BIAS = Z MIN                           00019900
      IF( ZSCALE(2) .NE. 0.00 ) Z BIAS = ZSCALE(2)                       00020000
      IF( ZSCALE(3) .EQ. 0.00 ) POWER = 0.25                             00020100
      IF( ZSCALE(3) .NE. 0.00 ) POWER = ZSCALE(3)                        00020200
      DBSCALE = 0.00                                                     00020300
      STEP = 1.00/LLEVELS                                                00020400
      PIOVER2 = 3.141592654/2.00                                         00020500
      RADIAN = PIOVER2*STEP                                              00020600
      DO 1066 L = 1,LLEVELS                                              00020700
      ARGUMENT = RADIAN*L                                                00020800
      ZLEVEL(L) = Z BIAS + ZREF*( (SINF(ARGUMENT))**POWER )              00020900
 1066 CONTINUE                                                           00021000
      SCALE = ZLEVEL(LLEVELS) - ZLEVEL(1)                                00021100
      ZRANGE = Z MAX - Z MIN                                             00021200
      GO TO 1075                                                         00021300
                                                                         00021400
 1070 ITYPE = BLNKFILL                                                   00021500
      ZRANGE = Z MAX - Z MIN                                             00021600
      SCALE = ZLEVEL(LLEVELS) - ZLEVEL(1)                                00021700
      DBSCALE = 0.00                                                     00021800
      Z BIAS = Z MIN                                                     00021900
      Z REF = Z MAX                                                      00022000
                                                                         00022100
C     THIS SECTION IS TESTING THE ARRAY WIDTH. THE LOGIC IS TO PRINT     00022110
C     OUT AS MANY OF THE COLUMNS AS WILL FIT ON A COMPUTER PAGE AT ONE   00022120
C     TIME. UP TO 128 COLUMNS CAN BE PRINTED ON ONE PAGE. IF MORE THAN   00022130
C     128 COLUMNS IN THE ARRAY, THEY ARE PRINTED IN BLOCKS OF 100.       00022140
C     ALL THE ROWS ARE PRINTED IN EACH BLOCK.                            00022150
                                                                         00022200
 1075 JBIAS = JLAST                                                      00022300
      IF( JYLENGTH .GT. 128 ) GO TO 1080                                 00022400
      NPAGES = 1                                                         00022500
      JLONG = JYLENGTH                                                   00022600
      IF( JYLENGTH .LT. 114 ) JSHIFT = 10                                00022700
      IF( JYLENGTH .GT. 113 ) JSHIFT = 0                                 00022800
      GO TO 2000                                                         00022900
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 1080 NPAGES = JYLENGTH/100                                                    00023000
      IF( JYLENGTH .GT. NPAGES*100 ) NPAGES = NPAGES + 1                       00023100
      JLONG = 100                                                              00023200
      JSHIFT = 10                                                              00023300
                                                                               00023400
                                                                               00023500
                                                                               00023600
 2000 DO 2500 NPAGE = 1,NPAGES                                                 00023700
                                                                               00023800
C     THIS IS THE PRINTING SECTION                                             00023810
C                                                                              00023820
C     THIS SECTION SELECTS THE PROPER BLOCK OF COLUMNS FOR PRINTING,           00023830
C     POSITIONS THE PLOTTING ON THE PAGE, AND SELECTS THE TYPE OF              00023840
C     ANNOTATION. A HEADER IS ALWAYS PRINTED FOR THE FIRST CALL AND            00023850
C     EXTENDED CALLS WITH RECOMPUTED SCALES.                                   00023860
                                                                               00023900
      JSTART = JBIAS + 1                                                       00024000
      JEND = MINOF( JBIAS+JLONG,JLAST+JYLENGTH )                               00024100
      IF( JSHIFT .EQ. 0 ) GO TO 2010                                           00024200
      IF( IEXTEND(2) .GT. 0 ) GO TO 2005                                       00024300
 2001 IF( NPAGE .GT. 1 ) JLEFT = 0                                             00024400
      IF( NPAGE .EQ. 1 ) JLEFT = 2                                             00024500
      IF( NPAGE .NE. NPAGES ) JRIGHT = 0                                       00024600
      IF( NPAGE .EQ. NPAGES ) JRIGHT = 2                                       00024700
      GO TO 2020                                                               00024800
 2005 IF( ISCALE .EQ. 1 ) GO TO 2001                                           00024900
      IF( NPAGE .EQ. 1 .AND. IEXTEND(2) .NE. 1 ) JLEFT = 2                     00025000
      IF( NPAGE .GT. 1 .OR.  IEXTEND(2) .GT. 1 ) JLEFT = 0                     00025100
      IF( NPAGE .EQ. NPAGES .AND. IEXTEND(2) .EQ. 3 ) JRIGHT = 2               00025200
      IF( NPAGE .LT. NPAGES .OR.  IEXTEND(2) .LT. 3 ) JRIGHT = 0               00025300
      GO TO 2020                                                               00025400
 2010 GO TO ( 2011,2012,2013 ) IEXTEND(2)                                      00025500
 2011 JLEFT = 2                                                                00025600
      JRIGHT = 1                                                               00025700
      GO TO 2020                                                               00025800
 2012 IF( ZSCALE(1) .EQ. 0.00 .OR. ZSCALE(1) .EQ.-1.00 ) GO TO 2011            00025900
      JLEFT = 0                                                                00026000
      JRIGHT = 0                                                               00026100
      GO TO 2020                                                               00026200
 2013 JSHIFT = -5                                                              00026300
      JLEFT = 1                                                                00026400
      JRIGHT = 2                                                               00026500
 2020 IF( IEXTEND(1) .LT. 2 ) GO TO 2100                                       00026600
      IF( ZSCALE(1) .EQ. 0.00 .OR. ZSCALE(1) .EQ.-1.00 ) GO TO 2100            00026700
      IF( IEXTEND(2) .LT. 1 .AND. NPAGES .EQ. 1 ) GO TO 2200                   00026800
                                                                               00026900
C     THIS SECTION GENERATES THE HEADER. NX AND NY ARE MATRIX INDEXING         00026910
C     OF THE ARRAY BLOCKS SENT SURFPLOT IN EXTENDED CALLS. NPAGE AND           00026920
C     NPAGES KEEP TRACK OF  THE BLOCKS OF COLUMNS USED IN PRINTING THE         00026930
C     LOCAL ARRAY.          THE BLOCKS OF COLUMNS USED IN PRINTING THE         00026940
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                                                                      00027000
      PRINT 92025, NX, NY, NPAGE, NPAGES                              00027100
92025 FORMAT(1HB,          *(*,I2,*,*,I2,*)*,3X,                       00027200
     1*SURFACE PLOT ..... PAGE *,I2,* OF *,I2 )                       00027300
      GO TO 2200                                                      00027400
                                                                      00027500
 2100 PRINT 92100, NX, NY, NPAGE, NPAGES                              00027600
92100 FORMAT(1HB, //,1H , *(*,I2,*,*,I2,*)*,3X,                       00027700
     1*SURFACE PLOT ..... PAGE *,I2,* OF *,I2, // )                   00027800
      PRINT 92101, ( ITITLE(L), L = 1,10 )                            00027900
92101 FORMAT(1H , 20X, 10( A8 ), // )                                 00028000
      PRINT 92102,                                                    00028100
     1    Z MAX, MAX X, MAX Y,                                       00028200
     2    Z MIN, MIN X, MIN Y,                                       00028300
     3    ZRANGE, ITYPE,                                             00028400
     4    ZLEVEL(LLEVELS),                                           00028500
     5    ZLEVEL(1),                                                 00028600
     6    SCALE, ITYPE,                                              00028700
     7    Z REF,                                                     00028800
     8    Z BIAS,                                                    00028900
     9    IXLENGTH, JYLENGTH,                                        00029000
     A    DBSCALE                                                    00029100
92102 FORMAT(1H , 20X,                                                00029200
     1*DATA MAXIMUM ..... *,E11.4,1X,*(*,I4,*,*,I4,*)*, /,1H , 20X,   00029300
     2*DATA MINIMUM ..... *,E11.4,1X,*(*,I4,*,*,I4,*)*, /,1H , 20X,   00029400
     3*DATA RANGE ....... *,E11.4,R2, //,1H , 20X,                    00029500
     4*SCALE MAXIMUM .... *,E11.4,  /,1H , 20X,                       00029600
     5*SCALE MINIMUM .... *,E11.4,  /,1H , 20X,                       00029700
     6*SCALE RANGE ...... *,E11.4,R2, //,1H , 20X,                    00029800
     7*PLOT REFERENCE ... *,E11.4,  /,1H , 20X,                       00029900
     8*PLOT BIAS ....... *,E11.4,  /,1H , 20X,                        00030000
     9*PLOT EXTENT ..... (*,I4,*,*,I4,*)*, //,1H , 20X,               00030100
     A*DB REFERENCE ..... *,F5.2, //,1H , 20X,                        00030200
     B*HALF TONE DENSITY WEDGE AND SCALE* )                           00030300
                                                                      00030400
C     THIS SECTION PRINTS THE DENSITY WEDGE OF GRAY SHADES AND THE    00030410
C     EQUIVALENT NUMERICAL VALUES, BOTH IN ABSOLUTE TERMS AND         00030420
C     RELATIVE TO THE REFERENCES.                                     00030430
                                                                      00030500
      IF( LLEVELS .GT. 10 ) GO TO 2125                                00030600
      IF( ITYPE .EQ. DBFILL ) GO TO 2105                              00030700
      DO 2103 L = 1,LLEVELS                                           00030800
      ZLEVEL(L) = ZLEVEL(L)/ZMAX                                      00030900
 2103 CONTINUE                                                        00031000
      PRINT 92103, ( ZLEVEL(L), L = 1,LLEVELS )                       00031100
92103 FORMAT(1H , 20X, 10( 2X,F5.3,*MAX* ) )                          00031200
      DO 2104 L = 1,LLEVELS                                           00031300
      ZLEVEL(L) = ZLEVEL(L)*ZMAX                                      00031400
 2104 CONTINUE                                                        00031500
      GO TO 2110                                                      00031600
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 2105 DO 2106 L = 1,LLEVELS                                                    00031700
      ZLEVEL(L) = DBSCALE*ALOG10( ZLEVEL(L)/ZMAX )                             00031800
 2106 CONTINUE                                                                 00031900
      PRINT 92106, ( ZLEVEL(L), L = 1,LLEVELS )                                00032000
92106 FORMAT(1H , 20X, 10( 1X,F7.2,*DB* ) )                                    00032100
      DO 2107 L = 1,LLEVELS                                                    00032200
      ZLEVEL(L) = ZMAX*( 10.00**( ZLEVEL(L)/DBSCALE ) )                        00032300
 2107 CONTINUE                                                                 00032400
 2110 PRINT 92110, ( ZLEVEL(L), L = 1,LLEVELS )                                00032500
92110 FORMAT(1H , 20X, 10( 1X,F9.2 ) )                                         00032600
      DO 2115 K = 1,3                                                          00032700
      DO 2115 L = 1,LLEVELS                                                    00032800
      IF( ISCALE(3) .EQ. 0 ) LPRINT = LBIAS + LSTEP*L                          00032900
      IF( ISCALE(3) .NE. 0 ) LPRINT = LBIAS + LSTEP*( LLEVELS+1-L )            00033000
      JEDGE1 = 21 + ( L-1 )*10                                                 00033100
      JEDGE2 = JEDGE1 + 9                                                      00033200
      DO 2115 J = JEDGE1,JEDGE2                                                00033300
      LINEPLOT(J,K) = LINESYM(LPRINT,K)                                        00033400
 2115 CONTINUE                                                                 00033500
      DO 2116 J = 1,20                                                         00033600
      LINE1(J) = LINE2(J) = LINE3(J) = BLANK                                   00033700
 2116 CONTINUE                                                                 00033800
      JEDGE1 = JEDGE2 + 1                                                      00033900
      DO 2117 J = JEDGE1,135                                                   00034000
      LINE1(J) = LINE2(J) = LINE3(J) = BLANK                                   00034100
 2117 CONTINUE                                                                 00034200
      DO 2120 I = 1,5                                                          00034300
      PRINT 92120, LINE1                                                       00034400
      PRINT 92120, LINE2                                                       00034500
92120 FORMAT(1H+, 135( A1 ) )                                                  00034600
      PRINT 92121, LINE3                                                       00034700
92121 FORMAT(1H , 135( A1 ) )                                                  00034800
 2120 CONTINUE                                                                 00034900
      GO TO 2150                                                               00035000
 2125 DO 2135 L = 1,LLEVELS                                                    00035100
      DO 2126 J = 1,135                                                        00035200
      LINE1(J) = LINE2(J) = LINE3(J) = BLANK                                   00035300
 2126 CONTINUE                                                                 00035400
      IF( ITYPE .EQ. DBFILL ) GO TO 2128                                       00035500
      ZLEVEL(L) = ZLEVEL(L)/ZMAX                                               00035600
      PRINT 92127, ZLEVEL(L)                                                   00035700
92127 FORMAT(1H+, 21X, F6.3,*MAX* )                                            00035800
      ZLEVEL(L) = ZLEVEL(L)*ZMAX                                               00035900
      GO TO 2130                                                               00036000
 2128 ZLEVEL(L) = DBSCALE*ALOG10( ZLEVEL(L)/ZMAX )                             00036100
      PRINT 92128, ZLEVEL(L)                                                   00036200
92128 FORMAT(1H+, 21X,F7.2,*DB* )                                              00036300
      ZLEVEL(L) = ZMAX*( 10.00**( ZLEVEL(L)/DBSCALE ) )                        00036400
 2130 IF( ISCALE(3) .EQ. 0 ) LPRINT = LBIAS + LSTEP*L                          00036500
      IF( ISCALE(3) .NE. 0 ) LPRINT = LBIAS + LSTEP*( LLEVELS+1-L )            00036600
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      DO 2131 K = 1,3                                                   00036700
      DO 2131 J = 31,40                                                 00036800
      LINEPLOT(J,K) = LINESYM(LPRINT,K)                                 00036900
 2131 CONTINUE                                                          00037000
      PRINT 92120, LINE1                                                00037100
      PRINT 92120, LINE2                                                00037200
      PRINT 92121, LINE3                                                00037300
      PRINT 92132, ZLEVEL(L)                                            00037400
92132 FORMAT(1H+, 21X,E9.2 )                                            00037500
      PRINT 92120, LINE1                                                00037600
      PRINT 92120, LINE2                                                00037700
      PRINT 92121, LINE3                                                00037800
 2135 CONTINUE                                                          00037900
                                                                        00038000
C     THIS SECTION IS NUMBERING THE COLUMNS (IN THE EXTENDED ARRAY       00038010
C     NUMEROLOGY).                                                      00038020
                                                                        00038100
 2150 DO 2151 K = 1,3                                                   00038200
      DO 2151 J = 1,135                                                 00038300
      LINEPLOT(J,K) = BLANK                                             00038400
 2151 CONTINUE                                                          00038500
      JEDGE1 = JSHIFT + 6                                               00038600
      JEDGE2 = JSHIFT + 8 + ( JEND-JSTART )                             00038700
      DO 2170 J = JSTART,JEND                                           00038800
      JPRINT = JSHIFT + 7 + J - JSTART                                  00038900
      IF( J .NE. MAX Y ) GO TO 2155                                     00039000
      LINE1(JPRINT) = MFILL                                             00039100
      LINE2(JPRINT) = AFILL                                             00039200
      LINE3(JPRINT) = XFILL                                             00039300
      GO TO 2170                                                        00039400
 2155 IF( J .NE. MIN Y ) GO TO 2160                                     00039500
      LINE1(JPRINT) = MFILL                                             00039600
      LINE2(JPRINT) = IFILL                                             00039700
      LINE3(JPRINT) = NFILL                                             00039800
      GO TO 2170                                                        00039900
 2160 INDEX = J - ( J/5 )*5                                             00040000
      IF( INDEX .NE. 0 ) GO TO 2170                                     00040100
      J1000 = ( J/1000 )                                                00040200
      J100  = ( J-J1000*1000 )/100                                      00040300
      J10   = ( J-J1000*1000-J100*100 )/10                              00040400
      J1    = ( J-J1000*1000-J100*100-J10*10 )                          00040500
      IF( J1000 .EQ. 0 ) GO TO 2164                                     00040600
 2161 LINE1(JPRINT) = J100                                              00040700
 2162 LINE2(JPRINT) = J10                                               00040800
 2163 LINE3(JPRINT) = J1                                                00040900
      GO TO 2170                                                        00041000
 2164 IF( J100  .EQ. 0 ) GO TO 2165                                     00041100
      GO TO 2161                                                        00041200
 2165 LINE1(JPRINT) = DOT                                               00041300
      IF( J10   .EQ. 0 ) GO TO 2166                                     00041400
```

```
      GO TO 2162                                                        00041500
 2166 LINE2(JPRINT) = DOT                                               00041600
      GO TO 2163                                                        00041700
 2170 CONTINUE                                                          00041800
      PRINT 92121, LINE1                                                00041900
      PRINT 92121, LINE2                                                00042000
      PRINT 92121, LINE3                                                00042100
 2190 DO 2191 J = JEDGE1,JEDGE2                                         00042200
      LINE1(J) = MESH                                                   00042300
      LINE2(J) = MESH                                                   00042400
      LINE3(J) = BLANK                                                  00042500
 2191 CONTINUE                                                          00042600
      IF( JLEFT .GT. 0 ) GO TO 2192                                     00042700
      LINE1(JEDGE1) = BLANK                                             00042800
      LINE2(JEDGE1) = BLANK                                             00042900
 2192 IF( JRIGHT .GT. 0 ) GO TO 2193                                    00043000
      LINE1(JEDGE2) = BLANK                                             00043100
      LINE2(JEDGE2) = BLANK                                             00043200
 2193 PRINT 92120, LINE1                                                00043300
      PRINT 92121, LINE2                                                00043400
      IF( IEXTEND(1) .LT. 2 ) GO TO 2200                                00043500
      PRINT 92195                                                       00043600
92195 FORMAT(1HB )                                                      00043700
                                                                        00043800
                                                                        00043900
C     THIS IS THE ACTUAL PRINTING SECTION FOR THE ARRAY OF F(X,Y)        00043910
C     VALUES. A SHADE OF GRAY IS ASSIGNED EACH (X,Y) LOCATION BY        00043920
C     DETERMINING WHICH ZLEVEL JUST EXCEEDS THE AMPLITUDE AT THAT       00043930
C     POINT. THE EQUIVALENT SHADE OF GRAY FOR THAT ZLEVEL IS THE        00043940
C     PRINTED REPRESENTATION OF F(X,Y). THIS COMPARISON IS DONE ROW      00043950
C     BY ROW. THE REMAINDER OF THIS SECTION IS SPEEDING UP THE I/O TO    00043960
C     THE LINE PRINTER.                                                 00043970
                                                                        00044000
                                                                        00044100
 2200 DO 2300 I = 1,IXLENGTH                                            00044200
      IX = I + ILAST                                                    00044300
      DO 2201 K = 1,3                                                   00044400
      DO 2201 J = 1,135                                                 00044500
      LINEPLOT(J,K) = BLANK                                             00044600
 2201 CONTINUE                                                          00044700
      DO 2215 J = JSTART,JEND                                           00044800
      JY = J - JLAST                                                    00044900
      INDEX = I + ( JY-1 )*IXLENGTH                                     00045000
      DO 2214 L = 1,LLEVELS                                             00045100
      IF( L .EQ. LLEVELS ) GO TO 2205                                   00045200
      ZTEST = ZDATA(INDEX)                                              00045300
      IF( ISCALE(4) .EQ. 0 ) GO TO 2202                                 00045400
      ZTEST = ITEST                                                     00045500
 2202 IF( ZTEST .GT. ZLEVEL(L) ) GO TO 2214                             00045600
 2205 JPRINT = JSHIFT + 7 + J - JSTART                                  00045700
```

```
      IF( ISCALE(3) .EQ. 0 ) LPRINT = LBIAS + LSTEP*L                    00045800
      IF( ISCALE(3) .NE. 0 ) LPRINT = LBIAS + LSTEP*( LLEVELS+1-L )      00045900
      DO 2210 K = 1,3                                                    00046000
      LINEPLOT(JPRINT,K) = LINESYM(LPRINT,K)                             00046100
 2210 CONTINUE                                                           00046200
      GO TO 2215                                                         00046300
 2214 CONTINUE                                                           00046400
 2215 CONTINUE                                                           00046500
 2220 IF( JLEFT .EQ. 0 ) GO TO 2221                                      00046600
      LINE1(JEDGE1) = MFILL                                              00046700
      LINE2(JEDGE1) = WFILL                                              00046800
 2221 IF( JRIGHT .EQ. 0 ) GO TO 2230                                     00046900
      LINE1(JEDGE2) = MFILL                                              00047000
      LINE2(JEDGE2) = WFILL                                              00047100
 2230 IF( IX .NE. MAX X ) GO TO 2240                                     00047200
      IF( JLEFT .LT. 2 ) GO TO 2231                                      00047300
      LINE1(JSHIFT+1) = MFILL                                            00047400
      LINE1(JSHIFT+2) = AFILL                                            00047500
      LINE1(JSHIFT+3) = XFILL                                            00047600
 2231 IF( JRIGHT .LT. 2 ) GO TO 2232                                     00047700
      LINE1(JEDGE2+3) = MFILL                                            00047800
      LINE1(JEDGE2+4) = AFILL                                            00047900
      LINE1(JEDGE2+5) = XFILL                                            00048000
      GO TO 2260                                                         00048100
 2232 IF( LINE1(JSHIFT+1) .EQ. MFILL ) GO TO 2260                        00048200
 2240 IF( IX .NE. MIN X ) GO TO 2250                                     00048300
      IF( JLEFT .LT. 2 ) GO TO 2241                                      00048400
      LINE1(JSHIFT+1) = MFILL                                            00048500
      LINE1(JSHIFT+2) = IFILL                                            00048600
      LINE1(JSHIFT+3) = NFILL                                            00048700
 2241 IF( JRIGHT .LT. 2 ) GO TO 2242                                     00048800
      LINE1(JEDGE2+3) = MFILL                                            00048900
      LINE1(JEDGE2+4) = IFILL                                            00049000
      LINE1(JEDGE2+5) = NFILL                                            00049100
      GO TO 2260                                                         00049200
 2242 IF( LINE1(JSHIFT+1) .EQ. MFILL ) GO TO 2260                        00049300
 2250 IF( JLEFT .LT. 2 .AND. JRIGHT .LT. 2 ) GO TO 2260                  00049400
      INDEX = IX - ( IX/5 )*5                                            00049500
      IF( INDEX .NE. 0 ) GO TO 2260                                      00049600
      I1000 = ( IX/1000 )                                                00049700
      I100  = ( IX-I1000*1000 )/100                                      00049800
      I10   = ( IX-I1000*1000-I100*100 )/10                              00049900
      I1    = ( IX-I1000*1000-I100*100-I10*10 )                          00050000
      IF( JLEFT .EQ. 2 ) ASSIGN 2251 TO JNEXT                            00050100
      IF( JLEFT .LT. 2 ) ASSIGN 2259 TO JNEXT                            00050200
      GO TO JNEXT, ( 2251,2259,2260 )                                    00050300
 2251 INDEX = JSHIFT + 1                                                 00050400
      ASSIGN 2259 TO JNEXT                                               00050500
 2252 IF( I1000 .EQ. 0 ) GO TO 2256                                      00050600
      LINE1(INDEX)   = I1000                                             00050700
```

```
 2253 LINE1(INDEX+1) = 1100                                              00050800
 2254 LINE1(INDEX+2) = 110                                               00050900
 2255 LINE1(INDEX+3) = 11                                                00051000
      GO TO JNEXT, ( 2251,2259,2260 )                                    00051100
 2256 LINE1(INDEX)   = 001                                               00051200
      IF( 1100  .EQ. 0 ) GO TO 2257                                      00051300
      GO TO 2253                                                         00051400
 2257 LINE1(INDEX+1) = 001                                               00051500
      IF( 110   .EQ. 0 ) GO TO 2258                                      00051600
      GO TO 2254                                                         00051700
 2258 LINE1(INDEX+2) = 001                                               00051800
      GO TO 2255                                                         00051900
 2259 IF( JRIGHT .LT. 2 ) GO TO 2260                                     00052000
      ASSIGN 2260 TO JNEXT                                               00052100
      INDEX = JEDGE2 + 2                                                 00052200
      GO TO 2252                                                         00052300
 2260 DO 2270 K = 1,3                                                    00052400
      DO 2270 J = 1,17                                                   00052500
      IF( J .EQ. 1 ) GO TO 2265                                          00052600
      INDEX = ( J-2 )*8 + 7                                              00052700
      LINEPLOT(INDEX+1,K) = ISHIFT1*LINEPLOT(INDEX+1,K)                  00052800
      LINEPLOT(INDEX+2,K) = ISHIFT2*LINEPLOT(INDEX+2,K)                  00052900
      LINEPLOT(INDEX+3,K) = ISHIFT3*LINEPLOT(INDEX+3,K)                  00053000
      LINEPLOT(INDEX+4,K) = ISHIFT4*LINEPLOT(INDEX+4,K)                  00053100
      LINEPLOT(INDEX+5,K) = ISHIFT5*LINEPLOT(INDEX+5,K)                  00053200
      LINEPLOT(INDEX+6,K) = ISHIFT6*LINEPLOT(INDEX+6,K)                  00053300
      LINEPLOT(INDEX+7,K) = ISHIFT7*LINEPLOT(INDEX+7,K)                  00053400
      JLINE(J,K) = LINEPLOT(INDEX+1,K) .OR. LINEPLOT(INDEX+2,K)          00053500
     1          .OR. LINEPLOT(INDEX+3,K) .OR. LINEPLOT(INDEX+4,K)       00053600
     2          .OR. LINEPLOT(INDEX+5,K) .OR. LINEPLOT(INDEX+6,K)       00053700
     3          .OR. LINEPLOT(INDEX+7,K) .OR. LINEPLOT(INDEX+8,K)       00053800
      GO TO 2270                                                         00053900
 2265 IF( K .EQ. 3 ) IPAGE = ISHIFT1*BLANK                               00054000
      IF( K .NE. 3 ) IPAGE = ISHIFT1*PLUS                                00054100
      LINEPLOT(1,K) = ISHIFT2*LINEPLOT(1,K)                              00054200
      LINEPLOT(2,K) = ISHIFT3*LINEPLOT(2,K)                              00054300
      LINEPLOT(3,K) = ISHIFT4*LINEPLOT(3,K)                              00054400
      LINEPLOT(4,K) = ISHIFT5*LINEPLOT(4,K)                              00054500
      LINEPLOT(5,K) = ISHIFT6*LINEPLOT(5,K)                              00054600
      LINEPLOT(6,K) = ISHIFT7*LINEPLOT(6,K)                              00054700
      JLINE(J,K) = IPAGE          .OR. LINEPLOT(1,K)                     00054800
     1          .OR. LINEPLOT(2,K) .OR. LINEPLOT(3,K)                   00054900
     2          .OR. LINEPLOT(4,K) .OR. LINEPLOT(5,K)                   00055000
     3          .OR. LINEPLOT(6,K) .OR. LINEPLOT(7,K)                   00055100
 2270 CONTINUE                                                           00055200
      PRINT 92270, JLINE                                                 00055300
92270 FORMAT( 17( A8 ) )                                                 00055400
 2300 CONTINUE                                                           00055500
                                                                         00055600
C     THIS SECTION IS NUMBERING THE COLUMNS (IN EXTENDED ARRAY           00055610
```

```
C     NUMEROLOGY).                                                          00055620
                                                                            00055700
      DO 2301 K = 1,3                                                       00055800
      DO 2301 J = 1,135                                                     00055900
      LINEPLOT(J,K) = BLANK                                                 00056000
 2301 CONTINUE                                                              00056100
      IF( IEXTEND(1) .EQ. 0 .OR. IEXTEND(1) .EQ. 3 ) JTAIL = 1              00056200
      IF( IEXTEND(1) .EQ. 1 .OR. IEXTEND(1) .EQ. 2 ) JTAIL = 0              00056300
      IF( JTAIL .EQ. 0 ) GO TO 2400                                         00056400
      JEDGE1 = JSHIFT * 6                                                   00056500
      JEDGE2 = JSHIFT * 8 * ( JEND-JSTART )                                 00056600
      DO 2302 J = JEDGE1,JEDGE2                                             00056700
      LINE1(J) = MFILL                                                      00056800
      LINE2(J) = WFILL                                                      00056900
 2302 CONTINUE                                                              00057000
      IF( JLEFT .GT. 0 ) GO TO 2303                                         00057100
      LINE1(JEDGE1) = BLANK                                                 00057200
      LINE2(JEDGE1) = BLANK                                                 00057300
 2303 IF( JRIGHT .GT. 0 ) GO TO 2304                                        00057400
      LINE1(JEDGE2) = BLANK                                                 00057500
      LINE2(JEDGE2) = BLANK                                                 00057600
 2304 PRINT 92120, LINE1                                                    00057700
      PRINT 92121, LINE2                                                    00057800
      LINE1(JEDGE1) = LINE1(JEDGE2) = BLANK                                 00057900
      LINE2(JEDGE1) = LINE2(JEDGE2) = BLANK                                 00058000
      DO 2320 J = JSTART,JEND                                               00058100
      JPRINT = JSHIFT * 7 * J - JSTART                                      00058200
      LINE1(JPRINT) = LINE2(JPRINT) = BLANK                                 00058300
      IF( J .NE. MAX Y ) GO TO 2305                                         00058400
      LINE1(JPRINT) = MFILL                                                 00058500
      LINE2(JPRINT) = AFILL                                                 00058600
      LINE3(JPRINT) = XFILL                                                 00058700
      GO TO 2320                                                            00058800
 2305 IF( J .NE. MIN Y ) GO TO 2310                                         00058900
      LINE1(JPRINT) = MFILL                                                 00059000
      LINE2(JPRINT) = IFILL                                                 00059100
      LINE3(JPRINT) = NFILL                                                 00059200
      GO TO 2320                                                            00059300
 2310 INDEX = J - ( J/5 )*5                                                 00059400
      IF( INDEX .NE. 0 ) GO TO 2320                                         00059500
      J1000 = J/1000                                                        00059600
      J100  = ( J-J1000*1000 )/100                                          00059700
      J10   = ( J-J1000*1000-J100*100 )/10                                  00059800
      J1    = ( J-J1000*1000-J100*100-J10*10 )                              00059900
      IF( J1000 .EQ. 0 ) GO TO 2314                                         00060000
 2311 LINE1(JPRINT) = J100                                                  00060100
 2312 LINE2(JPRINT) = J10                                                   00060200
 2313 LINE3(JPRINT) = J1                                                    00060300
      GO TO 2320                                                            00060400
 2314 IF( J100  .EQ. 0 ) GO TO 2315                                         00060500
```

```
      GO TO 2311                                                        00060600
 2315 LINE1(JPRINT) = DOT                                               00060700
      IF( J10    .EQ. 0 ) GO TO 2316                                    00060800
      GO TO 2312                                                        00060900
 2316 LINE2(JPRINT) = DOT                                               00061000
      GO TO 2313                                                        00061100
 2320 CONTINUE                                                          00061200
      PRINT 92121, LINE1                                                00061300
      PRINT 92121, LINE2                                                00061400
      PRINT 92121, LINE3                                                00061500
                                                                        00061600
 2400 JBIAS = JEND                                                      00061700
                                                                        00061800
                                                                        00061900
 2500 CONTINUE                                                          00062000
                                                                        00062100
C     THIS ENDS THE PRINTING SECTION.                                   00062110
C     THE EXTENDED ARRAY PARAMETERS ARE UPDATED IN THIS SECTION.        00062120
                                                                        00062200
                                                                        00062300
      IF( IEXTEND(1)*IEXTEND(2) .EQ. 0 ) GO TO 3020                     00062400
      IF( IEXTEND(1)*IEXTEND(2) .EQ. 9 ) GO TO 3015                     00062500
      GO TO ( 3001,3005,3010 ) IDXY + 1                                 00062600
 3001 ILAST = IXLENGTH                                                  00062700
      JLAST = JYLENGTH                                                  00062800
      NX = 0                                                            00062900
      NY = 0                                                            00063000
      GO TO 5000                                                        00063100
 3005 IF( IEXTEND(1) .EQ. 3 ) GO TO 3006                                00063200
      ILAST = ILAST + IXLENGTH                                          00063300
      NX = NX + 1                                                       00063400
      GO TO 5000                                                        00063500
 3006 ILAST = 0                                                         00063600
      JLAST = JLAST + JYLENGTH                                          00063700
      NX = 1                                                            00063800
      NY = NY + 1                                                       00063900
      GO TO 3016                                                        00064000
 3010 IF( IEXTEND(2) .EQ. 3 ) GO TO 3011                                00064100
      JLAST = JLAST + JYLENGTH                                          00064200
      NY = NY + 1                                                       00064300
      GO TO 5000                                                        00064400
 3011 JLAST = 0                                                         00064500
      ILAST = ILAST + IXLENGTH                                          00064600
      NY = 1                                                            00064700
      NX = NX + 1                                                       00064800
      GO TO 3016                                                        00064900
 3015 ILAST = JLAST = 0                                                 00065000
      NX = NY = 1                                                       00065100
      IDXY = 0                                                          00065200
 3016 PRINT 93016                                                       00065300
```

```
93016 FORMAT(1HB, // )                                                  00065400
      GO TO 5000                                                        00065500
                                                                        00065600
 3020 IF( IEXTEND(1) .NE. 0 ) GO TO 3040                                00065700
      IF( IEXTEND(2) .NE. 0 ) GO TO 3030                                00065800
      GO TO 3015                                                        00065900
 3030 IF( IEXTEND(2) .EQ. 3 ) GO TO 3015                                00066000
      JLAST = JLAST + JYLENGTH                                          00066100
      NY = NY + 1                                                       00066200
      GO TO 5000                                                        00066300
 3040 IF( IEXTEND(1) .EQ. 3 ) GO TO 3015                                00066400
      ILAST = ILAST + IXLENGTH                                          00066500
      NX = NX + 1                                                       00066600
                                                                        00066700
                                                                        00066800
                                                                        00066900
 5000 RETURN                                                            00067000
                                                                        00067100
                                                                        00067200
                                                                        00067300
      END                                                               00067400
```

6.0 COMPARISON

No equivalent plotting routine was found in the library.

7.0 TEST METHOD AND RESULTS

The following simple example, PRØGRAM TEST, illustrates the use of SURFPLØT.

```
      PROGRAM TEST

C THIS IS AN EXAMPLE PROGRAM USING SURF PLOT. THE FUNCTION BEING PLOTTED IS THE
C SUM OF TWO SINUSOIDS, ONE IN X AND ONE IN Y, ON A BIAS.

      DIMENSION A(72,100)
      DIMENSION ZDATA(72,100), ITITLE(10), ISCALE(4), ZSCALE(3)
      DIMENSION IEXTEND(2), ZLEVEL(10), ZPARAMTR(6)

      IXLENGTH = 72
      JYLENGTH = 100
      READ 90000, ( ITITLE(I), I = 1,10 )
90000 FORMAT( 10( A8 ) )

      PI = 3.1415926535
      RADIAN X = PI/12.0
      RADIAN Y = PI/20.0
      DO 1000 J = 1,100
      ARG Y = J*RADIAN Y
      PART Y = SINF( ARG Y )
      DO 1000 I = 1,72
      ARG X = I*RADIAN X
      PART X = SINF( ARG X )
      A(I,J) = 2.00 + PART X + PART Y
 1000 CONTINUE

      CALL SURF PLOT ( A, IXLENGTH, JYLENGTH, ITITLE, ISCALE, ZSCALE,
     1   ZLEVEL, ZPARAMTR, IEXTEND, ISEARCH )

      END
```

```
THE FUNCTION IS F(X,Y) = 2.00 + SINF(PI*I/12.00) + SINF(PI*J/20.00)
```

(1, 1) SURFACE PLOT ..... PAGE 1 OF 1

THE FUNCTION IS F(X,Y) = 2.00 + SINF(PI*I/12.00) + SINF(PI*J/20.00)

DATA MAXIMUM ..... 4.0000+000 (6, 10)
DATA MINIMUM ..... 0.0000+000 (18, 30)
DATA RANGE .... 4.0000+000

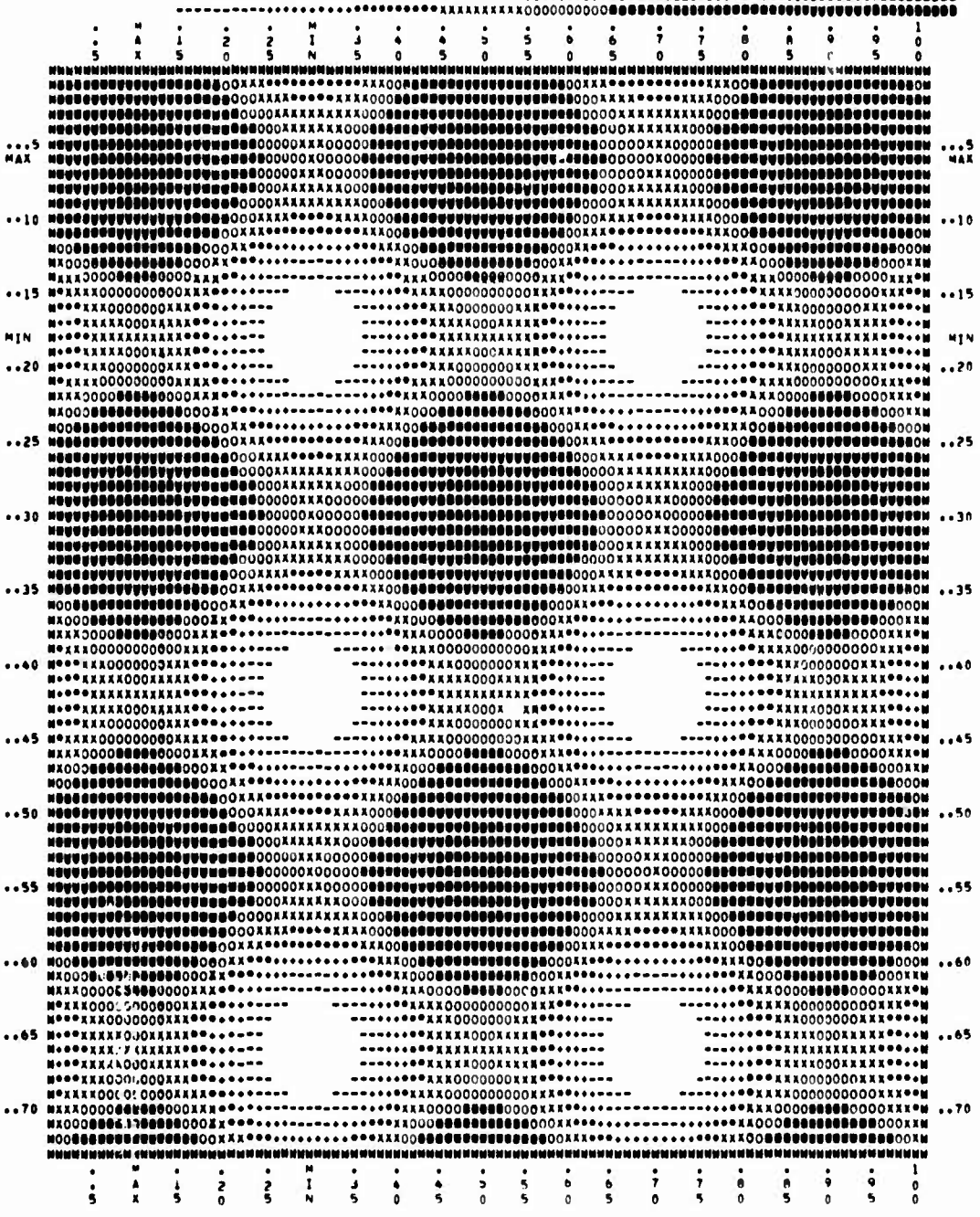
SCALE MAXIMUM ..... 4.0000+000
SCALE MINIMUM 4.0000-001
SCALE RANGE .... 3.6000+000

PLOT REFERENCE ..... 4.0000+000
PLOT BIAS .... 0.0000+000
PLOT EXTENT .... (72, 100)

DB REFERENCE 0.00

HALF TONE DENSITY #EDGE AND SCALE

0.100*MAX	0.200*MAX	0.300*MAX	0.400*MAX	0.500*MAX	0.600*MAX	0.700*MAX	0.800*MAX	0.900*MAX	1.000*MAX
4.00-001	8.00-001	1.20+000	1.60+000	2.00+000	2.40+000	2.80+000	3.20+000	3.60+000	4.00+000



8.0 REMARKS

The "writing speed" of the line printer is not high. The technique used here depends strongly on the natural spatial integration done by the eye. If the structures change quickly, e.g., in the span of one element to its neighbor, then the detail will not be perceived.

The gray scale used in SURFPLØT is one selected after some trial and error. It is by no means unique. There is literature on the subject, although the only reference consulted was Knuth [1]. The user who wants to develop a different gray scale can either (1) use more than ten shades in which case this subroutine requires a new gray scale or (2) change the internal gray scale contained in the data statements for LINESYM. One technique of interest is to "go around the gray scale" several times to obtain more shades. That is, using the same symbols in cycles. The author would be interested to see other gray scales generated using the line printer.